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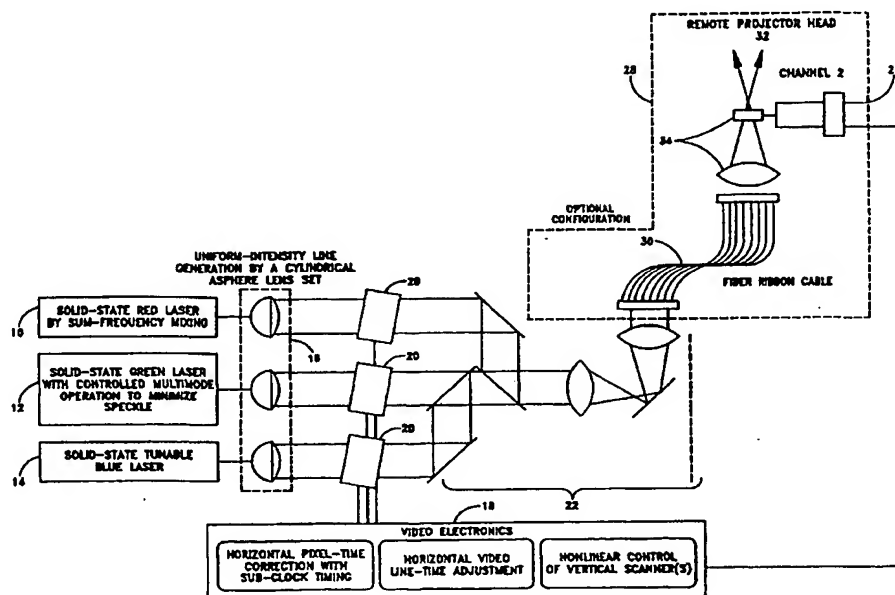
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(57) Abstract

A full color, pulsed laser video system having solid state red (R), green (G) and blue (B) lasers (10, 12, 14) as a source, and with a projection screen having a two-channel image (24) for the screen, and with optical fiber remote image delivery (30).

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## Description

## LASER VIDEO DISPLAY SYSTEM AND METHOD

Reference to Prior Applications

This application incorporates by reference and claims the  
5 benefit of U.S. Provisional Application Serial No. 60/036,437,  
filed January 28, 1997.

Background of the Invention

A pulsed laser video imaging system and method is set  
forth in U.S. Patent Nos. 4,720,747 and 4,851,918, issued on  
10 January 19, 1988, and July 25, 1989, respectively, both hereby  
incorporated by reference. These patents describe a video  
imaging system responsive to input signals representing a video  
image and employ one or more pulsed lasers, such as metal vapor  
lasers, to provide one or more monochromatic light sources.

15 Summary of the Invention

The invention relates to a laser video display system and  
method. In particular, the invention relates to a full color,  
laser video image system wherein the pulsed laser light source  
comprises a green (G) laser with controlled multimode operation  
20 to minimize speckle, a tunable blue (B) laser and a red (R)  
laser with sum of frequency mix.

It is desirable to provide a new and improved pulsed laser  
projection system and method with one or more of the following  
improvements. The list of improvements include:

- 25 1. all solid state green laser design with controlled  
multimode operation to minimize speckle;
2. all solid state tunable blue laser design;
3. all solid state red laser design with sum of  
frequency mix;
- 30 4. diode laser pumped, all solid state, monochromatic  
red, green and blue light source with color space conversion;
5. uniform intensity line generation by a cylindrical  
asphere lens set;
6. two channel image output with achromatic image  
35 inversion;

7. remote image delivery by coherent fiber ribbon;
8. horizontal video line time adjustment (compression and expansion);
9. nonlinear control of vertical scanner (i.e.,  
5 tangential correction); and
10. horizontal pixel time correction with sub-clock timing.

The various components of the improved laser video image system and method, and the differences and improvements from  
10 prior art systems and methods are set forth in detail below.

- (1) All solid state green laser design with controlled multimode operation to minimize speckle.

The original invention described in U.S. Patent No. 4,720,747 specifies the use of metal vapor lasers as light  
15 sources. U.S. Patent No. 3,818,129, issued June 18, 1974, to Yamamoto, incorporates use of a cw lamp pumped, repetitively Q-switched, frequency doubled Neodymium:Yttrium Aluminum Garnet (Nd:YAG) laser (wavelength = 532nm) to be a light source for green, and it cites the short pulse duration and high average  
20 power as the primary reasons for the choice of the above-mentioned laser. However, U.S. Patent No. 3,818,129 fails to mention another important factor affecting image quality, which is output beam quality from the above-mentioned laser.

Generally speaking, the output beam quality from the cw  
25 lamp pumped, repetitively Q-switched, frequency doubled, Nd:YAG laser with high output power tends to have a high multimode structure in transverse direction, which results in high beam divergence; therefore producing undesirable image blur at a screen. The above-mentioned laser can be constructed to  
30 produce near diffraction limited, single mode output ( $TEM_{00}$  mode) which minimizes the beam divergence; however,  $TEM_{00}$  mode output does maximize laser speckle effect, which is not desirable.

Then what is needed is the cw lamp pumped, repetitively Q-  
35 switched, frequency doubled Nd:YAG laser cavity design which

produces controlled multimode output in transverse direction that minimizes the laser speckle and still produces reasonably crisp images on the screen surface because of optically manageable beam divergence.  $M^2$  is a measurable quantity which characterizes output beam spot size at far field and its divergence. When  $M^2$  is equal to one, the output beam is called diffraction limited beam or TEM<sub>00</sub> mode, whereas when  $M^2$  is large (i.e., ~100), then the output beam is said to have a high multimode structure. The acceptable range of  $M^2$  for the laser video display discussed in this invention is semi-empirically determined to be between 10 and 20. To achieve the acceptable range of  $M^2 = 10-20$ , the cw lamp pumped, repetitively Q-switched, frequency doubled Nd:YAG laser has an intra-cavity aperture to strip excess modes, and the frequency doubling process is achieved by a Type II LBO (lithium triborate) or KTP (potassium titanyl phosphate) placed within the laser cavity. The schematic drawing of this green laser cavity is shown in Fig. 3.

(2) All solid state tunable blue laser

Blue light is produced by a frequency doubled Ti:Sapphire (Ti:Al<sub>2</sub>O<sub>3</sub>) laser, which is longitudinally pumped by the cw lamp pumped, repetitively Q-switched, frequency doubled Nd:YAG laser (wavelength = 532nm). The Ti:Al<sub>2</sub>O<sub>3</sub> laser has broad range of near infrared emission; thus, it can be tuned to a specific wavelength by a set of birefringent plates, and for this particular application, the IR emission is tuned at 900nm. The frequency doubling process is achieved by placing a Type I LBO or BBO (beta-barium borate) within the Ti:Al<sub>2</sub>O<sub>3</sub> laser cavity (i.e., intra-cavity frequency doubling), which results in emission of blue light at 450nm. Finally, the range of blue emission from this frequency doubled Ti:Al<sub>2</sub>O<sub>3</sub> laser can be tunable by adjusting the angle of the birefringent plates. The schematic drawing of the frequency doubled Ti:Al<sub>2</sub>O<sub>3</sub> laser is shown in Fig. 4.

(3) All solid state red laser with sum of frequency mix.

A cw lamp pumped, repetitively Q-switched Nd:YAG laser produces primary laser radiation of 1064nm. This 1064nm radiation is used to pump the potassium titanyl arsenate (KTA) based intracavity optical parametric oscillation (OPO) and sum of frequency mix (SFM) mechanism to produce red light in wavelength between 626nm and 629nm. When KTA crystal is pumped by 1064nm, it has been demonstrated to produce the signal (1520nm~1540nm) and the idler (~3540nm) waves, and unlike KTP, the KTA does not exhibit reabsorption of the idler wavelength (~3540nm); thus, relatively high conversion efficiency is expected from KTA based OPO once the pump beam exceeds OPO threshold. A separate Type III KTP will be used to achieve the sum of frequency mix process, and it has a phase match angle of 77° for SFM process between the wavelength of 1520nm~1540nm and 1064nm, producing the resultant red wavelength of between 626nm and 629nm. Similarly, Type II KTA or Type I LBO can be used to achieve sum of frequency mix (SFM) between 1520~1540nm and 1064nm to produce the desired red wavelength of 626~629nm, instead of Type III KTP discussed above.

The lasing mechanism to generate 1064nm radiation, and KTA based OPO, and subsequent KTP based SFM process can be placed in the same cavity structure (intra-cavity design) or the two can be separated, depending on peak power of 1064nm radiation. The schematic drawing of the former cavity design is shown in Figure 5.

(4) Diode laser pumped, all solid state, monochromatic red, green and blue light source with color space conversion.

The all solid state red, green and blue laser designs discussed previously are based on cw lamp pump mechanism to produce primary laser radiation of 1064nm from Nd:YAG crystal. However, diode laser pumped, all solid state red, green and blue laser light source described in U.S. Provisional Patent Application No. 60/032,269, filed November 29, 1996 (Title: "Monochromatic R,G,B Laser Light Source and Display Systems by

Masayuki Karakawa), will also be used as an alternative light source to produce three primary colors. This diode laser pumped, all solid state red (wavelength: 626-629nm), green (wavelength: 532 or 523.5nm) and blue (wavelength: 450 or 447nm) laser light source also incorporates digital color space conversion electronics circuit and produces a very short pulse at a high repetition rate.

(5) Uniform intensity line generation by a cylindrical asphere lens set.

10 In the laser video projection system described in U.S. Patent Nos. 4,720,747 and 4,851,918, each pulse of laser light having Gaussian intensity distribution, from one or more laser source must be converted to a line by an optical set up, and enters into an acousto-optic cell which acts as a spatial light  
15 modulator. In this process it is important to have the optical set up, which converts the laser beam having circular cross section and Gaussian intensity distribution into a well-collimated, uniform intensity, thin line, in order to have good image quality at the screen and achieve maximum coupling with  
20 the acousto-optic cells.

In U.S. Patent Nos. 4,720,747 and 4,851,918, the optical set up, which consists of a pair of cross-cylinder lenses with a collimator is suggested, and in U.S. Patent No. 3,818,129, no particular optical set up is mentioned in this area. A pair of  
25 cross-cylinder lenses with a collimator approach does produce a line; however, the intensity distribution and the line thickness are not uniform across the line.

The improved optical set up disclosed herein consists of a cylindrical asphere lens and a pair of cylinder lenses  
30 cemented together to form a collimator set. The primary function of the cylindrical asphere lens is to convert a laser beam with circular cross section and Gaussian intensity distribution into a uniform intensity thin line, and the collimator set, made of a pair of cylinder lenses cemented back  
35 to back, keeps the line stray collimated at far field. An

aspherical surface of the cylindrical asphere lens is given by equation:

$$X = cy^2/[1 + (1 - c^2y^2(1+k))^{1/2}] + A_4y^4 + A_6y^6 + A_8y^8 + A_{10}y^{10} + \text{-----}$$

where k is conic constant and c is curvature.

5 It is very important to note that inclusion of the higher order terms (i.e.,  $A_4y^4$ ,  $A_6y^6$ ,  $A_8y^8$ ,  $A_{10}y^{10}$ , -----) are essential to produce uniform intensity distribution across the entire line; thus, they should not be overlooked. The higher order coefficients such as  $A_4$ ,  $A_6$ ,  $A_8$ ,  $A_{10}$ , -----  
10 are determined based on the precise spatial intensity distribution (a measurable quantity) of the source laser beam.

(6) Two channel image output with achromatic image inversion.

15 For a certain application, it is desirable to project two identical images on two different screen surfaces by one projector. To achieve this effect, it is necessary to:

1. split the image in half by trichroic beam splitter, which transmits 50% of the image through and also reflects  
20 the remaining 50% of the image;

2. apply necessary achromatic corrections to the reflected image to compensate color differences among red, green and blue, since the coating on the trichroic beam splitter may not divide red, green and blue images exactly in  
25 half;

3. then invert the reflected image, so that its geometry is the same as the transmitted one; and

4. finally, two images, the transmitted and reflected ones, are vertically scanned by two galvanometer driven  
30 scanners, controlled by the single electronic circuit, so that the two images are always at sync.

The schematic drawing of optical set up to achieve two image output, with achromatic image inversion, as described above is shown in Fig. 6.



(7) Remote image delivery by coherent fiber ribbon.

For a certain applications, it is desirable to decouple a main portion of the laser video projector mechanism, which includes red, green and blue lasers, three acousto-optic  
5 cells, and other optical components up to zero order focus (ZOF) beam block and a projector head, which includes the galvanometer driven vertical scanner and projection optics, and then connect them with fiber cable.

Since prior to launching into fiber all the imaging  
10 functions, including line-thickness control, and R,G,B field matching have been performed, the fiber cable used here should be  $1 \times N$  coherent fiber ribbon, where  $N$  should be a sufficiently large number (integer) and preferably close to the number of horizontal pixels. The coherent fiber ribbon  
15 set up is necessary to preserve already encoded video images from one end of the fiber to the other end.

Two different applications are envisioned for this remote image delivery method by  $1 \times N$  coherent fiber ribbon. The first application is single projector/single display use,  
20 and the second application is single projector/multiple display use. The only difference between the two applications is that in the second application, the image is divided in half by a fused fiber image divider prior to launching into two separate  $1 \times N$  coherent fiber ribbons,  
25 which are then connected to two separate projector heads.

The single projector/single display application is shown in Fig. 7 and the single projector/multiple display application is shown in Fig. 8.

(8) Horizontal video line time adjustment (compression  
30 and expansion).

In U.S. Patent Nos. 4,720,747 and 4,851,918, electronic video line time compression (or data compression) concept is included. This allows the use of a smaller size aperture, acousto-optic cell; thus, enabling the input laser light to

attain high diffraction efficiency into the first order when the input signal considered is NTSC video signal only.

However, there are many other video signal formats available now, and for certain input signals applications, it is desirable and necessary to expand the input video line time. For example, consider the input signal having the resolution of 1280 (H) pixels by 1024 (V) lines at 72 Hz refresh rate with progressive scan format (non-interlace format): The horizontal video line time for this input signal is approximately equal to 11-12 $\mu$ s; whereas, the necessary aperture time for the acousto-optic cell is approximately equal to 22 $\mu$ s, if the multi-line writing scheme is implemented. Furthermore, for an anisotropic, acousto-optic cell, such as TeO<sub>2</sub>, operating in sheer mode, there is not much difference in diffraction efficiencies into the first order between 11 $\mu$ s (horizontal length ~ 6.8mm) aperture and 22 $\mu$ s (horizontal length ~ 13.6mm). Therefore, what is needed is not just video line time compression, but video line time adjustment, which includes compression and expansion means to manipulate input video line time best suited for different applications.

The input video line time expansion can be achieved in a similar manner as video line time compression by:

1. storing input each horizontal video line data into line or frame buffers momentarily;
2. retrieving the stored data from the line or frame buffers with different rates from the input video signal;
3. sending the output video signal to one or more transducers attached to acousto-optic cells; and
4. when the output video signal rate is shorter than the input one, the signal is compressed; whereas, if the output video signal rate is longer than the input one, the signal is expanded in time domain.

## (9) Nonlinear control of vertical scanner.

Generally speaking, a galvanometer based vertical scanner, driven by linear ramp signal, makes incremental vertical sweep, with equally spaced angular displacement for  
 5 given oscillation rate, and its linearity (i.e., each angular displacement) is known to be excellent.

However, when the galvanometer based vertical scanner is used to project each horizontal video line onto the screen surface with relatively short throw distance, the equally  
 10 spaced angular displacement motion of the vertical scanner, driven by a series of linear ramp signals, does not translate into equal spatial spacing of each horizontal line at the screen surface. The actual result is that the horizontal line spacing is closer together at the top and bottom of the  
 15 screen, and they are more apart at the center of the screen. In order to achieve equal spatial spacing of each horizontal line at the screen surface, the galvanometer driven vertical scanner has to be driven by nonlinear ramp signals, providing unequally spaced angular displacement motion.

20 Refer to Fig. 9, which shows each angular displacement of the vertical scanner and the screen surface, the  $i^{\text{th}}$  incremental angular displacement made by the vertical scanner resulting in the projection of the  $i^{\text{th}}$  horizontal line onto the screen is given by the equation:

$$25 \quad A_i = \text{ArcTan} [ \text{Tan} (A_{i-1} + A_{i-2} + A_{i-3} + \text{-----} + A_2 + A_1) + \text{Tan} A_1 ] - (A_{i-1} + A_{i-2} + A_{i-3} + \text{-----} + A_2 + A_1)$$

Where:  $A_1 = \text{ArcTan} (L/D)$

L = Identical spacing for each horizontal line at the screen surface =  $H/N$

30 H = Height of the screen

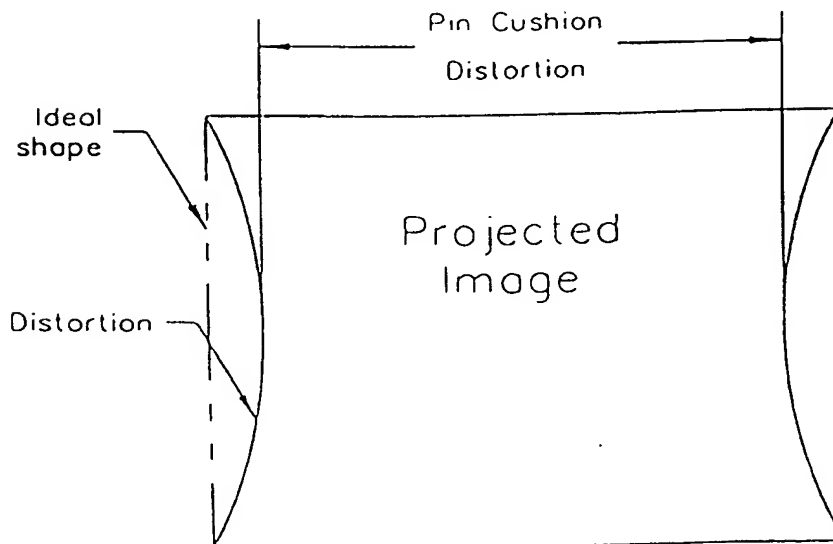
N = Total number of horizontal lines = vertical resolution of the image

D = Distance between the scanner and the center of the screen

The nonlinear angular displacement of the vertical scanner given by the equation above is used to calculate each angular displacement corresponding to each projected horizontal line, and the results can be programmed into look up tables within firmware, then the programmed data can be used to provide necessary electronics correction to ramp signal (tangential correction) which drives the vertical scanner.

(10) Horizontal pixel time correction with sub-clock timing.

When the laser video projector described in this invention is used with relatively short throw distance from the screen surface, the projected image suffers from a distortion known as "pin cushion" effect as illustrated below.



This distortion originates from the fact that it takes a longer time for a pixel to reach the upper or lower section

of the screen than to reach the center section of the screen; therefore, the pixels at the top and bottom section of the screen expand more than those at the center section, resulting in the image having bow-shaped left and right  
5 edges.

In order to correct this image distortion, pixel by pixel-based time correction is needed such a manner, that additional time is assigned to a group of pixels corresponding to the center section of the image; whereas,  
10 lesser time is assigned to a group of pixels corresponding to the four upper and lower corners of the image. This pixel time correction is implemented within the acousto-optic cell in the following manner:

Consider a case with a video pixel time equal to 28ns.  
15 Normally, this pixel signal is generated by 36 MHz master clock ( $f=1/28\text{ns}$ -36MHz) and pixel time interval does not change across the given video line within the acousto-optic cell. However, the additional sub-clock circuit oscillating at 500 MHz will provide  $\pm 2\text{ns}$  change into the master clock  
20 circuit oscillating at 36 MHz, and the result enables the combined clock signal circuits to generate pixel time varying  $(28 \pm 2 \cdot N)\text{ns}$  (where  $N$  is integer = 0, 1, 2,...). With this additional sub-clock circuit, the pixel time can be adjusted across the given video line so that shorter pixel time is  
25 assigned to a group of pixels at the both edges and longer time is assigned to a group of pixels at the center section of the video line.

This pixel time correction with sub-clock circuit produces the predistorted image within the acousto-optic  
30 cell, which will compensate for the "pin cushion" problem at the screen surface, resulting in an image with straight line left and right edges as desired.

The invention will be described for the purpose of illustration only in connection with certain illustrated  
35 embodiments; however, it is recognized that various changes,

modifications, additions and improvements may be made in the illustrative embodiments without departing from the spirit and scope of the invention.

#### Brief Description of the Drawings

5 The laser video image system has been described with various improvements and components, implying particular red (R), green (G), and blue (B) lasers as the laser light source; however, it is recognized that other embodiments alone, or in combination, as described and shown, may be  
10 employed with other and prior art pulsed laser sources.

Fig. 1 is a functional block flow diagram of a video display system of the invention.

Fig. 2 is a functional block flow diagram of another embodiment of the system of the invention.

15 Fig. 3 is a solid state green laser cavity design.

Fig. 4 is a solid state tunable blue laser cavity design.

Fig. 5 is a solid state red laser cavity design.

Fig. 6 is a two channel output with achromatic image  
20 inversion.

Fig. 7 is a remote image delivery by coherent fiber ribbon (single projector/single display)

Fig. 8 is a remote image delivery by coherent fiber ribbons (single projector/multi-display)

25 Fig. 9 is a tangential correction for vertical scanner.

#### Description of the Embodiments

Fig. 1 shows a functional block flow diagram of a laser video display system discussed in this invention, which consists of an all solid state R, G, B pulsed laser light  
30 sources that comprise a red laser 10 utilizing sum of frequency mix to generate desirable red wavelength, a green laser 12 with controlled multimode operation to minimize speckle and a wavelength tunable blue laser 14.

The system includes a cylindrical asphere lens set 16  
35 which generates uniform intensity line from output beam of

each R, G, B pulsed laser light source. The system also includes a video electronic circuit 18 that includes horizontal pixel time correction with sub-clock timing mechanism, horizontal video line time adjustment and  
5 nonlinear control of vertical scanner angles; and an acousto-optical modulator 20 with transducers (shown here as AOM) which receives corrected video signals in a form of RF signals from the video electronics circuit. The system includes beam reflective and lens optics formation to combine  
10 separate R, B, G images to form a full color image.

Also shown in Fig. 1 is an optional optical design utilizing 50/50 trichroic beam splitter 24 to divide the full color image in half (the transmitted one and the reflected one), then apply achromatic correction and image inversion  
15 onto the reflected image, and finally, vertically scan the two images with two scanners 26 driven in sync to each other.

Fig. 2 shows a functional block flow diagram of a laser video display system discussed in this invention, which consists of:

- 20 i) all solid state R,G, and B pulsed laser light sources which comprise a red laser 10 utilizing sum of frequency mix to generate desirable red wavelength, a green laser 12 with controlled multimode operation to minimize speckle, and wavelength tunable blue laser 14;
- 25 ii) a cylindrical asphere lens set 16 which generates uniform intensity line from output beam of each R, G, B pulsed laser light source;
- iii) video electronics circuit 18 which includes horizontal pixel time correction with sub-clock timing  
30 mechanism, horizontal video line time adjustment and nonlinear control of vertical scanner angles;
- iv) acousto-optical modulator 20 with transducers [shown here as AOM (acousto-optical modulator)] which receives corrected video signals in a form of RF signals from  
35 the video electronics circuit; and

v) R,G, B formation optics 22 to combine separate R,G, B images to form a full color image.

Also shown in Fig. 2 is an optional full color image delivery design 28 by coherent fiber ribbon to the remote locations. This remote image delivery by coherent fiber ribbon 30 enables the decoupling of the main body of the laser video projection system and relatively smaller size projection head 32 which consists of a vertical scanner 26 and a set of projection optics 34.

There are two possible applications of this remote image delivery by coherent fiber ribbon 30:

i) to connect the laser video projection system and one projector head 32; or

ii) to connect the laser video projection system with 50/50 beam splitter incorporated and two independent projector heads.

Fig. 3 shows an optical layout of the solid state green laser with controlled multimode operation. The green laser uses an L-shaped cavity formed by two cavity end mirrors (M1 and M2) and an output coupler (OC). Inside this cavity, there is a cw lamp pumped Nd:YAG rod housed in a laser pump chamber (YAG), an acousto-optic Q-switch (QS) which provides repetitive pulsing operation, an intra-cavity focusing lens (L1), a nonlinear crystal (KTP) which converts 1064nm emission from Nd:YAG into 532nm, and an intra-cavity aperture (AP), which controls output mode of operation. The green beam exits the laser at the output coupler (OC) and travels through a series of turning mirrors (TM1-TM3), a collimating lens (L2) and a zoom telescope (TELESCOPE), before entering a cylindrical asphere lens (POW) which converts a laser beam having Gaussian intensity distribution into a thin line of uniform intensity.

Finally, instead of Type II KTP shown in Fig. 3, an alternative frequency doubling crystal option is Type II LBO.



Fig. 4 shows an optical layout of the solid state, pulsed blue laser. The similar pulsed green laser, utilizing cw lamp pumped Nd:YAG disclosed in solid state, pulsed green laser embodiment, minus the intra-cavity aperture, produces a high powered, pulsed green beam. It exits from a green laser output coupler (GOC) and travels through a series of turning mirrors (GTM1-GTM3) and a collimating lens (L2). It longitudinally pumps a Ti:Al<sub>2</sub>O<sub>3</sub> (Ti:S) rod, which is located inside of a V-shaped cavity formed by two blue cavity end mirrors (BM1 and BM2) and a blue output coupler (BOC). The output laser emission from the Ti:Al<sub>2</sub>O<sub>3</sub> rod is tuned to approximately 900nm by coatings of blue laser cavity optics and intra-cavity placement of a birefringent plate (BRF). Depending on wavelength tunability requirements, multilayers of birefringent plates may be used. The 900nm emission is intra-cavity, frequency-doubled to produce blue emission of 450nm by a nonlinear crystal (LBO). Alternatively, Type I BBO can be used instead of Type I LBO shown in Fig. 4. The cylindrical asphere lens (POW) placed outside the blue laser cavity performs the uniform intensity line generation task.

Fig. 5 shows a schematic layout of the solid state, pulsed red laser. A cw lamp pumped Nd:YAG produces 1064nm laser emission and repetitive pulsing action is performed by an acousto-optic or electro-optic Q-switch. Pumped by pulsed 1064nm emission, a nonlinear crystal KTA produces emission of 1520-1540nm through an optical parametric oscillation (OPO) process. A separate nonlinear crystal Type III KTP combines 1520-1540nm emission from KTA and 1064nm emission from Nd:YAG through sum of frequency mix (SFM) process to produce red emission of 626-629nm, which exits from an output coupler (OC). Although Type III KTP is shown in Fig. 5 as a nonlinear crystal to perform sum of frequency mix operation, another KTA or Type I LBO can be used for the SFM process.

Finally, Fig. 5 shows all the components in the same cavity (intra-cavity design); however, the sum of frequency mix process may be performed in a separate cavity.

The all solid state red, green and blue pulsed laser  
5 embodiments disclosed here are incorporated in laser video projection system shown in Figs. 1 and 2.

Fig. 6 shows more detailed optical design incorporating 50/50 trichroic beam splitter and optical means to invert the reflected image, so that its image geometry is the same as  
10 the transmitted one.

Schematic design diagrams illustrating these two separate applications are shown in Fig. 7 and Fig. 8 respectively.

Fig. 9 describes the desired effect of tangential  
15 correction on a projection screen 40 (or image plane) when the vertical scanner 26 is driven by a ramp signal, including nonlinear tangential correction discussed in this invention.

Fig. 9 shows a line spacing between each horizontal line (shown here as the width of each horizontal line) equal to L,  
20 which is equal to  $H/N$ , where H is the height of the screen and N is the total number of horizontal lines of the image (vertical resolution of the image).

Claims

What is claimed is:

Claim 1. A full color laser video image system, which  
2 system comprises:

a) a pulsed laser light source to provide a pulsed  
4 laser beam, which comprises:

i) an all solid state green (G) laser with  
6 controlled multimode operation to minimize speckle;  
ii) an all solid state tunable blue (B) laser; and  
8 iii) an all solid state red (R) laser utilizing  
sum of frequency mix;

10 b) an acoustical-optical cell means to provide sound  
transmittal and a transducer to produce sound waves;

12 c) signal means to drive the transducer and provide an  
input video signal and an output video signal;

14 d) a projection means to produce a full color laser  
video image; and

16 e) a projection screen with a surface to receive and  
display the full color projection image.

Claim 2. The system of claim 1 wherein the projection  
2 means includes an optical subsystem, which comprises a  
cylinder asphere lens and a pair of cylinder lens to convert  
4 the laser beam into a collimated, uniform intensity thin  
line.

Claim 3. The system of claim 1 which includes:

2 i) a beam splitter means to split the full color  
video image in half, to transmit one-half of the video image  
4 and to reflect the other half of the video image;

ii) means to apply achromatic correction on the  
6 reflected half of the video image;

iii) means to invert the reflected half of the  
8 video image to the same image geometry as the transmitted  
image; and

10           iv) means to scan vertically the corrected,  
inverted, reflected half of the video image and transmitted  
12 image to synchronize said two images.

Claim 4. The system of claim 3 which includes means to  
2 deliver the full color image by a coherent fiber ribbon.

Claim 5. The system of claim 1 which includes  
2 electronic means to provide horizontal video line data  
expansion, which comprises:

- 4           i) means to store an input video data signal into  
line or frame buffers;  
6           ii) means to retrieve the stored data at a  
different rate than the input video data signal;  
8           iii) means to transmit an output video data signal  
at a slower rate than the input video data signal rate; and  
10          iv) means to transmit the retrieved stored data  
signal to the one or more transducers on the acoustical-cell  
12 means.

Claim 6. The system of claim 1 wherein the green (G)  
2 laser comprises a cw lamp pumped, repetitively Q-switched,  
frequency doubled Nd:YAG laser.

Claim 7. The system of claim 1 wherein the blue (B)  
2 laser comprises a frequency doubled, Ti:Sapphire laser which  
is longitudinally pumped by a cw lamp, repetitively Q-  
4 switched, frequency doubled Nd:YAG laser.

Claim 8. The system of claim 7 which includes a  
2 birefringent plate to receive the laser light from the  
Ti:Sapphire laser; and means to adjust the angle of  
4 birefringent plate to tune the blue light wavelength  
desirable.

Claim 9. The system of claim 1 wherein the red (R)  
2 laser comprises:

- i) a cw lamp pumped, repetitively, Q-switched  
4 Nd:YAG laser to produce a 1064nm beam;  
          ii) a potassium titanyl arsenate (KTA) pumped by  
6 the 1064nm beam to produce 1520-1540nm beams; and

iii) a sum of frequency mix to produce red (R) light of 626nm and 629nm.

Claim 10. The system of claim 4 which includes:

- i) a first optical image divider means to divide the full color image in half;
- ii) first and second coherent fiber ribbons, each to receive the half image; and
- iii) a first and second projection head which includes a set of optics and a vertical scanner connected to the first and second ribbons respectively.

Claim 11. The system of claim 1 which includes a nonlinear controlled vertical scanner means, driven by nonlinear ramp signals, to provide an equally-spaced angular displacement motion of each horizontal line on the projection screen surface.

Claim 12. The system of claim 1 which includes means to correct the "pin cushion" effect of the projection image on the projection screen, and to increase the pixel time corresponding to the center of the projection image, and to decrease the pixel time at or about the four corners of the projection image.

Claim 13. The system of claim 12 which includes a master clock circuit for pixel interval and a sub-clock circuit to correct pixel time across a given horizontal video line of the projection image.

Claim 14. A method for displaying laser-based video projection images on a projection screen, which method comprises:

- a) projecting full color video images corresponding to electrical signals representing the full color images onto a projection screen, and employing as the light source for the images:
  - i) a diode laser pumped, all solid state, pulsed green (G) laser to produce green output of 532nm or 523.5nm with controlled multimode operation to minimize speckle;

- ii) a diode laser pumped, all solid state,  
12 pulsed blue (B) laser with blue output of 450nm or 447nm; and  
iii) a diode laser pumped, all solid state,  
14 pulsed red (R) laser with sum of frequency mix means to  
produce red output between 626nm and 629nm..

Claim 15. A full color laser video system which  
2 comprises a pulsed laser light source with an input beam;  
means to modulate the input beam to provide electrical  
4 signals representative of the video image; and projection  
means to project the image onto a projection screen for  
6 display, which system includes:

- a) a beam splitter means to split the video image  
8 in half; and to transmit one-half the video image and to  
reflect the other half of the video image;  
10 b) means to correct achromatically the reflected  
half of the video image;  
12 c) means to invert the reflected half of the  
video image; and  
14 d) means to scan vertically the corrected,  
inverted, reflected half of the video image and the  
16 transmitted half of the video image to provide a  
synchronized, full color video image on two different  
18 projection screens.

Claim 16. A full color laser video system which  
2 comprises a pulsed laser light source with an input beam;  
means to modulate the input beam to provide electrical  
4 signals representative of the video image; and projection  
means to project the image onto a projection screen for  
6 display, which system includes an input video line time  
expansion system, which comprises:

- 8 i) means to store in memory momentarily, an input  
video data signal into line or frame buffers;  
10 ii) means to retrieve the stored data signal from  
memory at a different rate than the input video data signal;

12                   iii) means to transmit the output video data  
signal at a rate slower than the input video data signal; and  
14                   iv) means to transmit an output video data signal  
to one or more sound modulating transducers, on one or more  
16 acousto-optic cells.

                  Claim 17. A full color laser video image system which  
2 comprises a pulsed laser light source with an input beam;  
means to modulate the input beam to provide electrical  
4 signals representative of the video image; and projection  
means to project the image onto a projection screen for  
6 display, which system includes:

                  a) a remote video image delivery system, which  
8 comprises:

                  i) a coherent optical fiber ribbon means to  
10 transmit from the one and to the other end of the coherent  
fiber ribbon, an encoded full color video image to a  
12 projector head, which includes a set of optics and a vertical  
scanner for projection of the full color video image onto the  
14 projection screen.

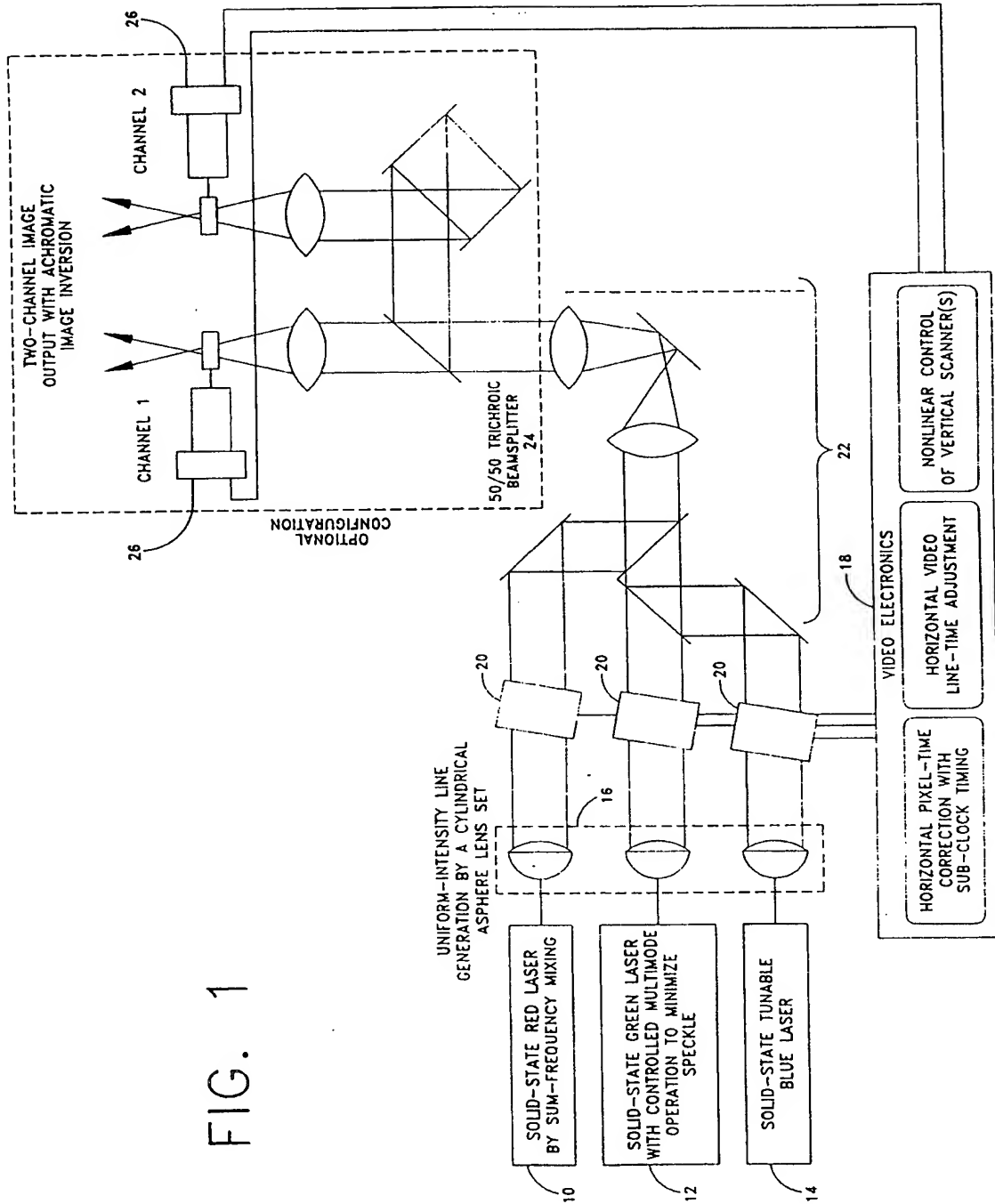
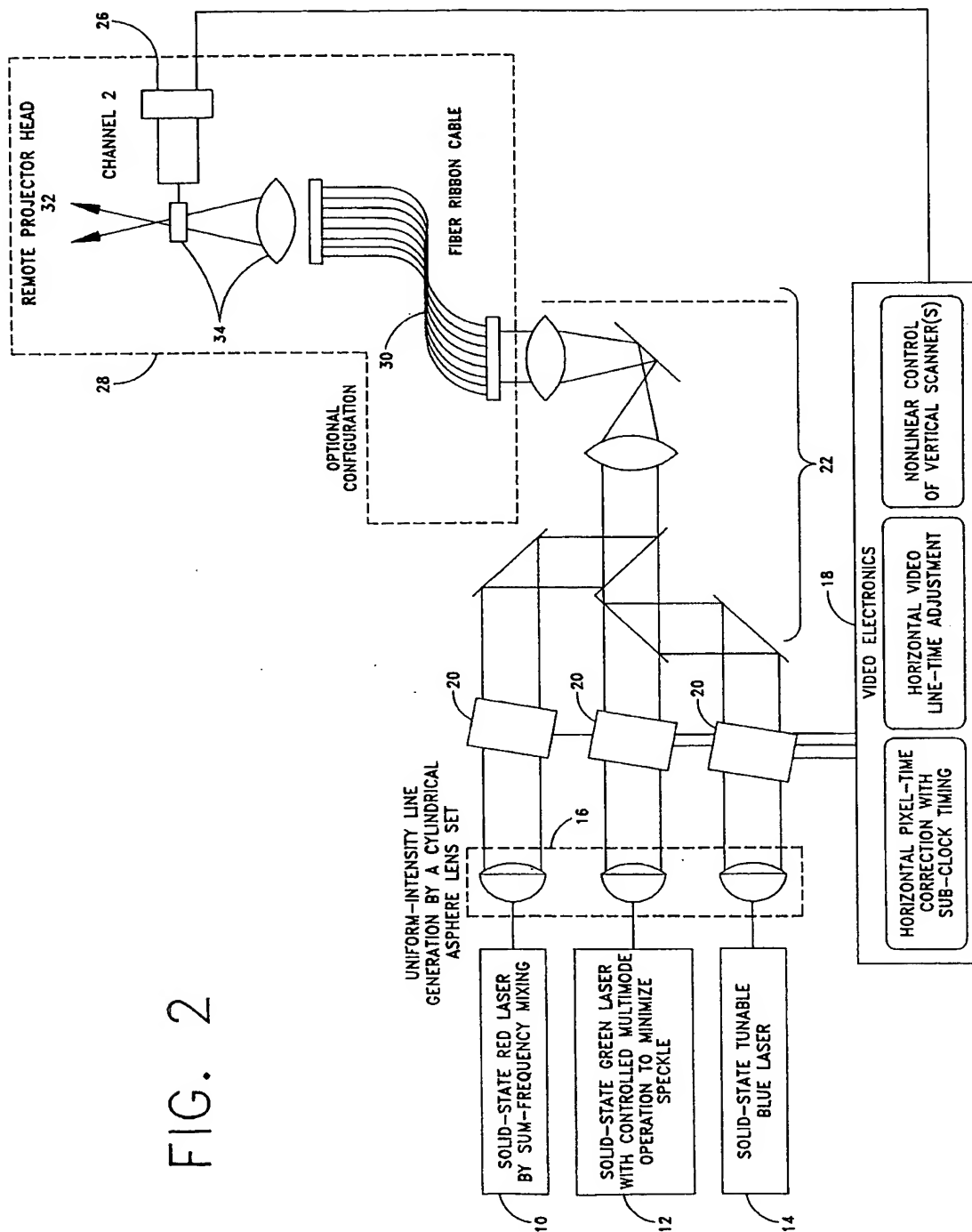


FIG. 1



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FIG. 2



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GREEN LASER OPTICS SCHEMATIC

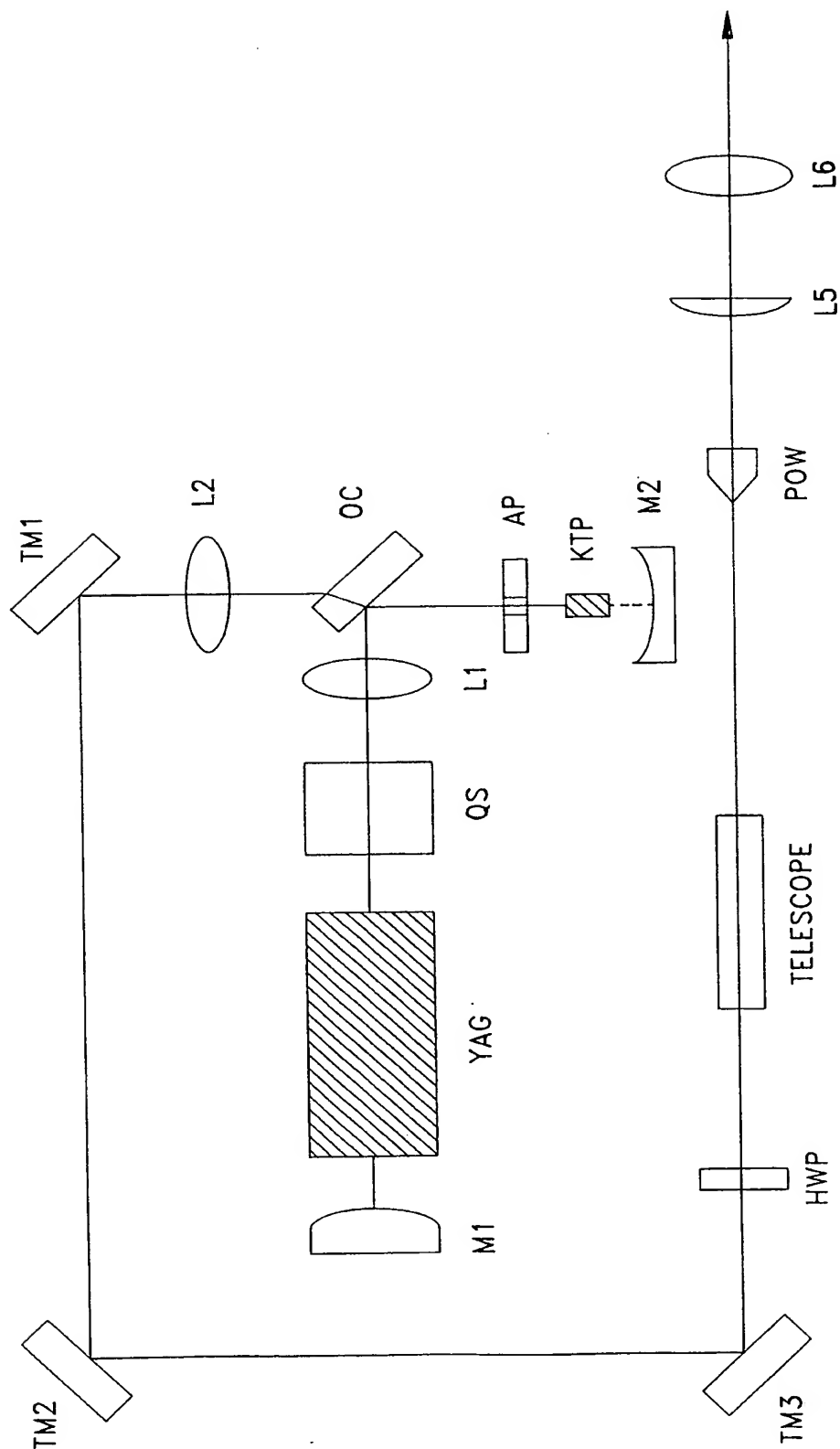


FIG. 3

BLUE LASER OPTICS SCHEMATIC

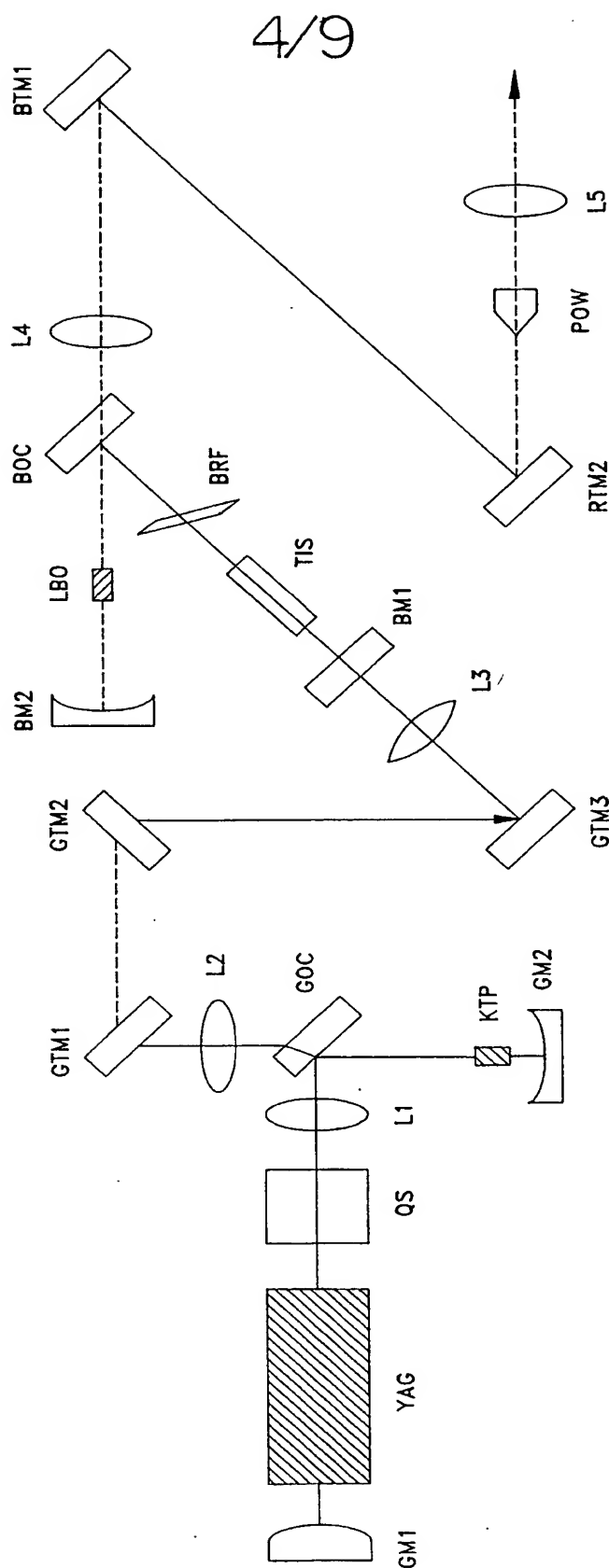


FIG. 4

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## SOLID STATE RED LASER DESIGN

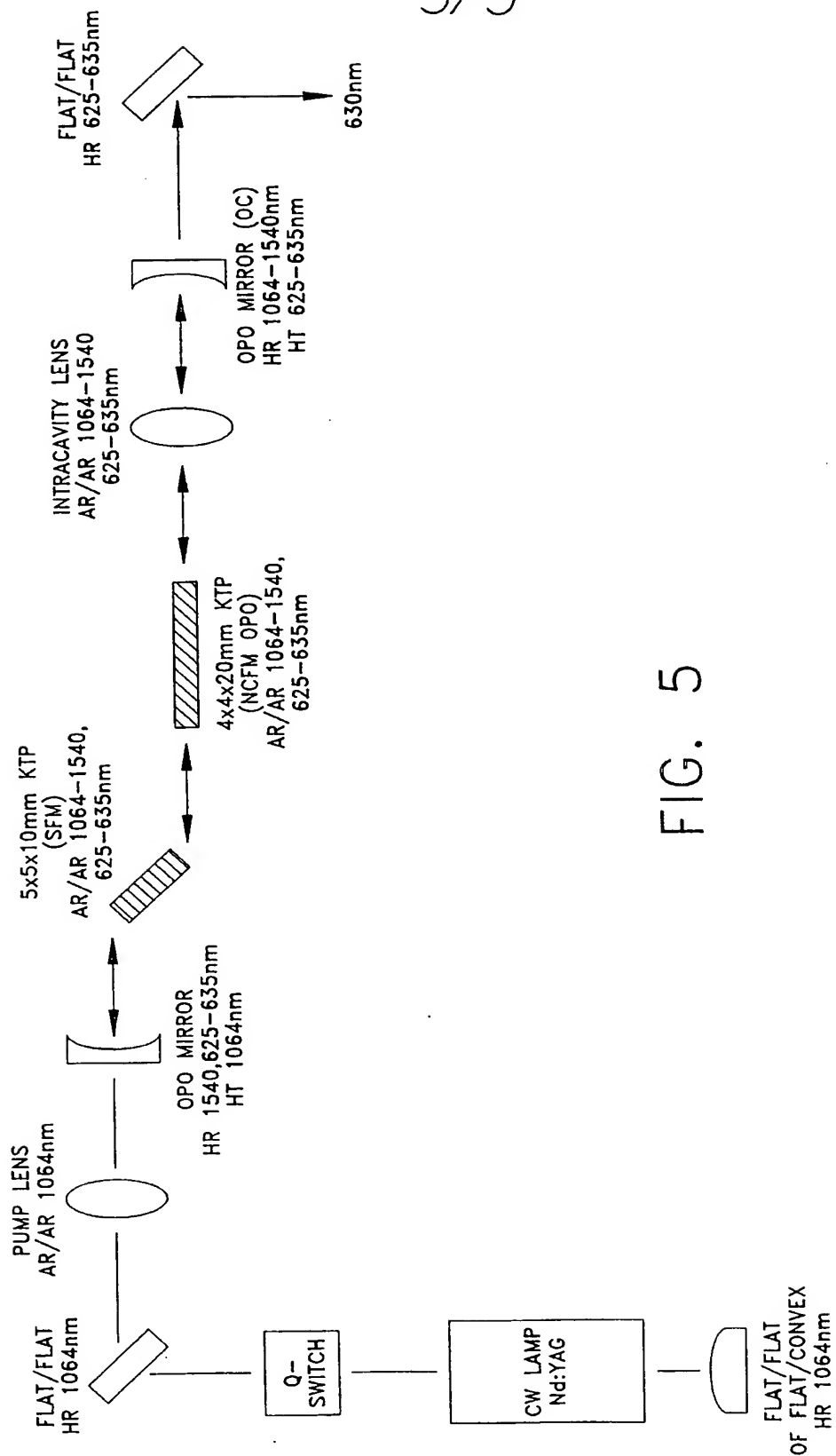


FIG. 5

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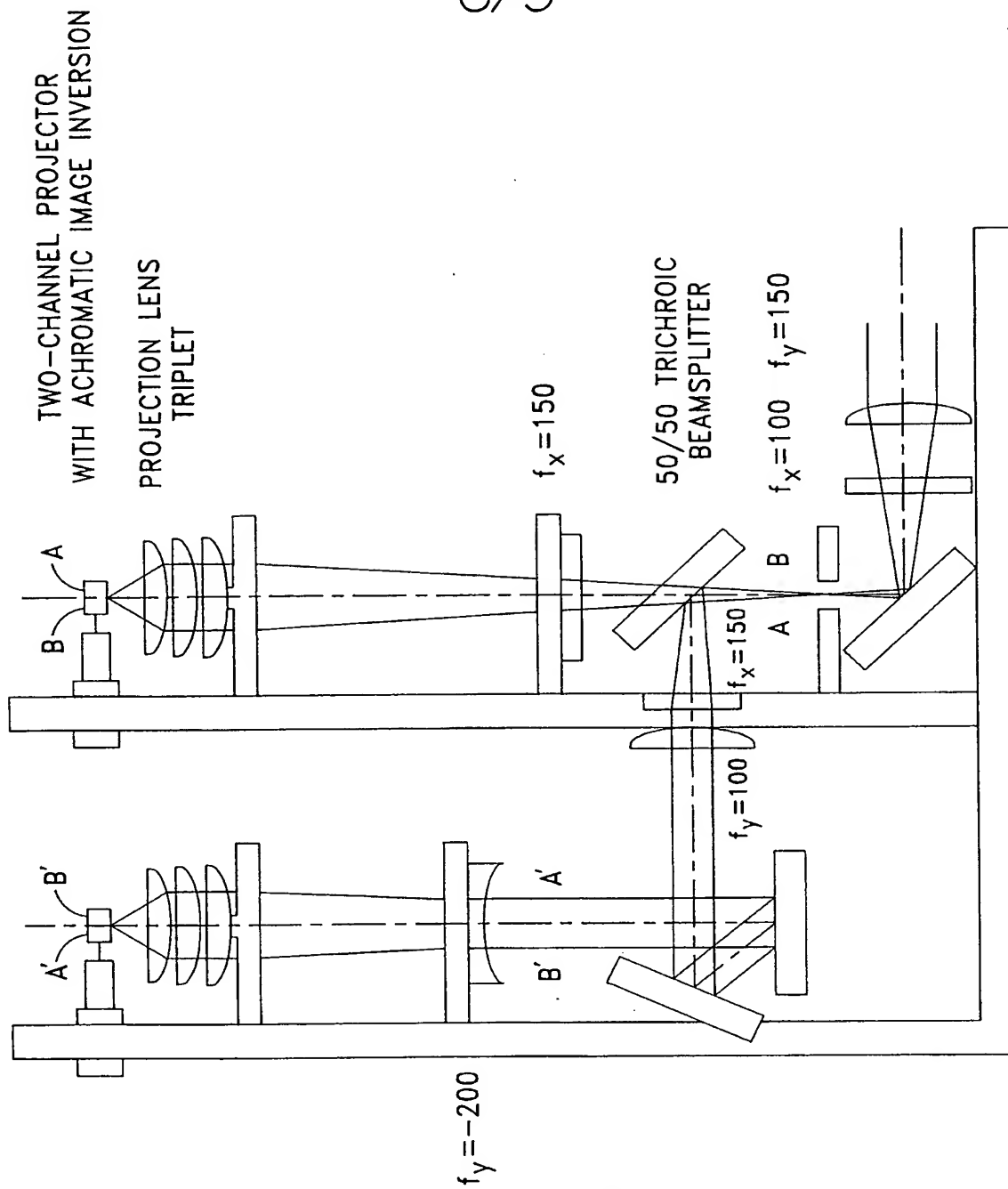


FIG. 6

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# FIBER-COUPLING STRATEGIES

## A. SINGLE-PROJECTOR/SINGLE-DISPLAY

CONFIGURATION A-1:

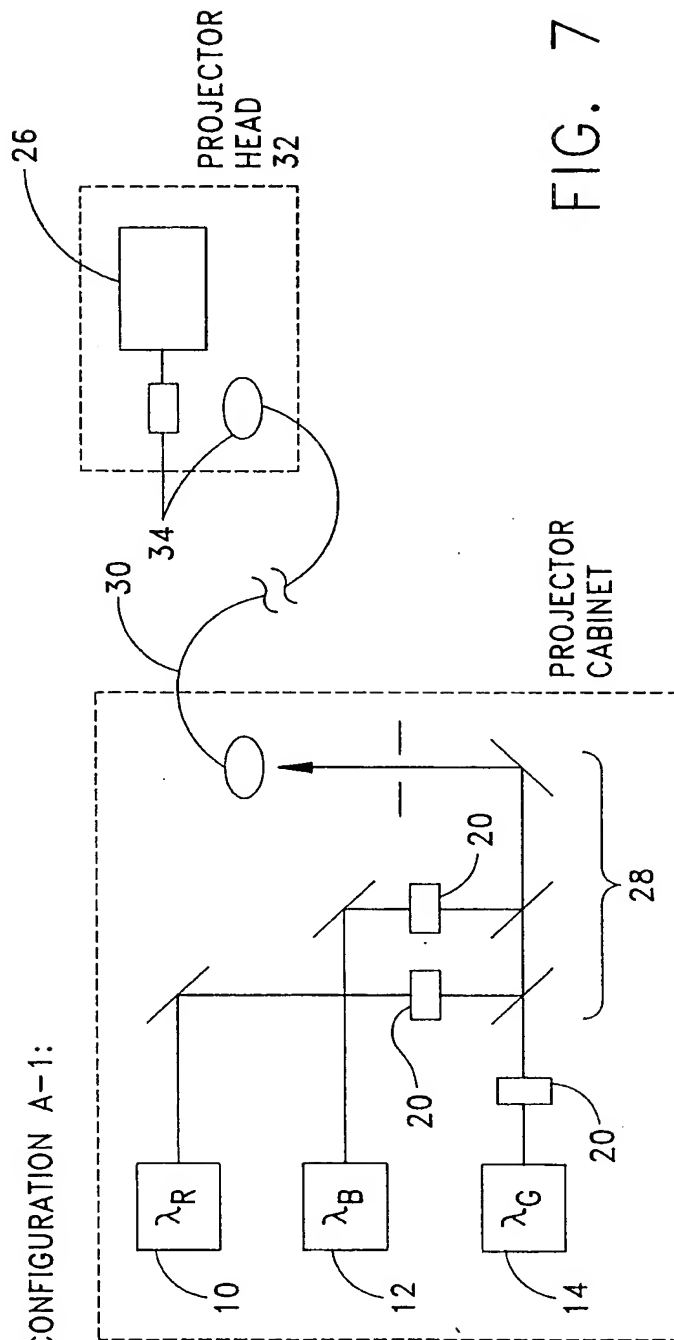


FIG. 7

### OPTICAL DESIGN IMPACT

- ALL THREE COLORS COUPLED INTO ONE FIBER RIBBON CABLE.
- PROJECTION TRIPLET AND SCANNER IN HEAD UNIT.
- AO IMAGING, LINE-THICKNESS, FIELD-MATCHING AND ZOF PRIOR TO LAUNCHING INTO FIBER.

## FIBER-COUPLING STRATEGIES

## B. SINGLE-PROJECTOR/MULTIPLE-DISPLAYS

CONFIGURATION B-1:

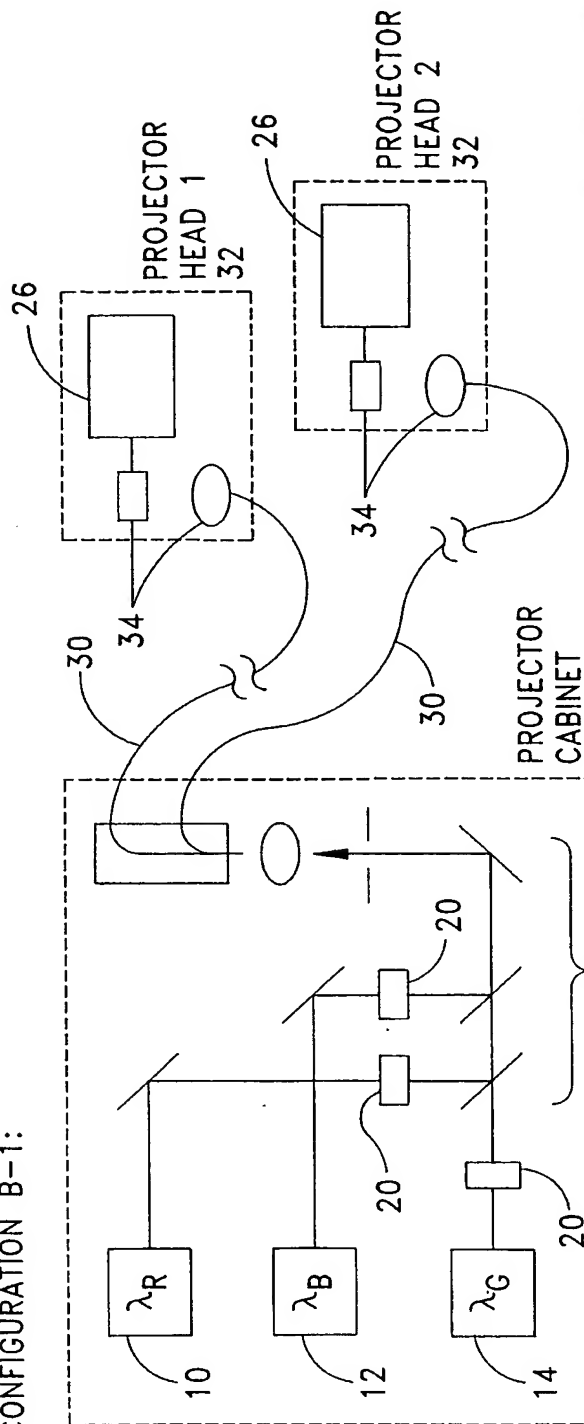


FIG. 8

## OPTICAL DESIGN IMPACT

- ALL THREE COLORS COUPLED INTO A FUSED FIBER IMAGE DIVIDER FOR 50/50 INTENSITY SPLIT.
- FIBER RIBBON CABLES DELIVER IMAGES TO SEPARATE PROJECTOR HEADS.
- PROJECTION TRIPLET AND SCANNER IN HEAD UNIT.
- AO IMAGING, LINE-THICKNESS, FIELD-MATCHING AND ZOF PRIOR TO LAUNCHING INTO FIBER.

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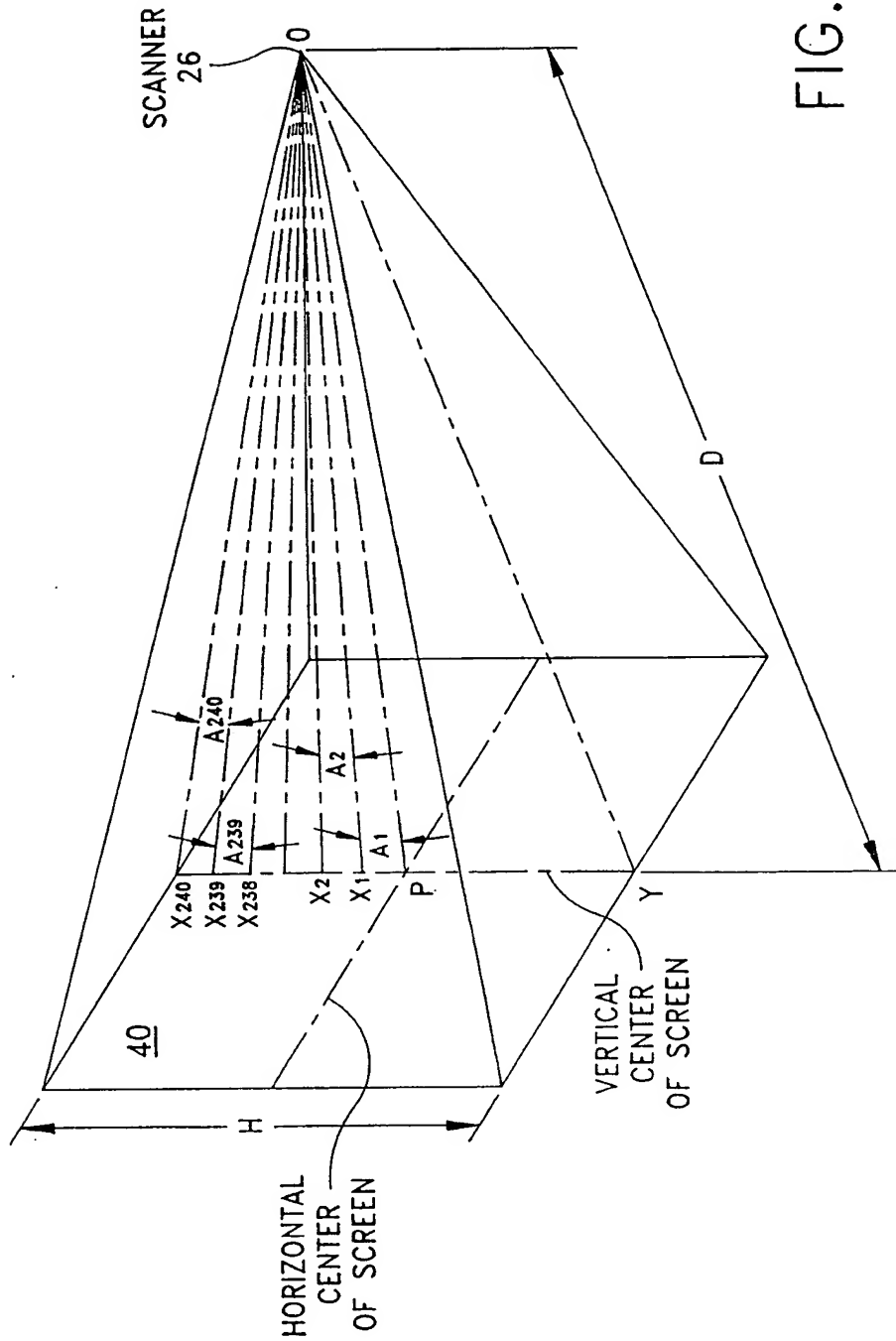


FIG. 9

$\overline{X_{240}}$  : HALF OF SCREEN VERTICAL HEIGHT =  $H/2$

O P : DISTANCE BETWEEN SCANNER AND THE CENTER OF SCREEN = D

N : TOTAL NO. OF VERTICAL SCAN LINES (NTSC SPEC. 480 LINES SHOWN)

$\overline{X_{240} X_{239}} = \overline{X_{239} X_{238}} = \overline{X_{238} X_{237}} = \overline{X_2 X_1} = L$  (WIDTH OF EACH HORIZONTAL LINE)



## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/01719

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H04N 9/31; G02F 1/00.

US CL : 348/750, 760; 353/31; 359/216.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 348/750, 760, 756, 757, 754, 769-772, 190-205; 353/31, 34, 37; 359/216, 217, 214, 212.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No.                        |
|-----------|--|--|
| X         | US 5,253,073 A (CROWLEY) 12 OCTOBER 1993, COL, 3, LINE 59, TO COL. 8, LINE 36.     | 1, 2, 5, 6, 7, 8, 9, 11, 12, 13, 14, 16, 17. |
| A         | US 5,317,348 A (KNIZE) 31 MAY 1994, THE WHOLE DOCUMENT.                            | 1-17   |
| X         | US 4,851,918 A (CROWLEY) 25 JULY 1989, COL. 4, LINE 25, TO COL. 13, LINE 66.       | 16   |
| A,E       | US 5,715,021 A (GIBEAU ET AL.) 03 FEBURARY 1998, THE WHOLE DOCUMENT.               | 1-17   |



Further documents are listed in the continuation of Box C.



See patent family annex.

|   |     |  |
|---|-----|--|
| * Special categories of cited documents:  | *T  | later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention  |
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| *E* earlier document published on or after the international filing date  | *Y* | document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art |
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| *O* document referring to an oral disclosure, use, exhibition or other means  |     |  |
| *P* document published prior to the international filing date but later than the priority date claimed  |     |  |

Date of the actual completion of the international search

17 APRIL 1998

Date of mailing of the international search report

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